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Organizational Capital and the International Co-movement of Investment

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Abstract

A productivity shock leads to a large international transfer of capital and negative co-movement of investment in the typical two-country real business cycle model. Most recent models that attempt to reduce or remove this transfer produce unrealistically low investment volatility. We show that adding organizational capital to the technological environment of a relatively standard international business cycle model can ameliorate this problem. In addition we show that GHH preferences along with the above modification are sufficient to deliver positive cross-country correlations of consumption, hours, output and investment.

Keywords: International RBC, learning by doing, organizational capital, cross-country correlations, investment.

JEL classification: F41,F21,E32

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1. Introduction

While there is clear evidence that business cycles are correlated in developed countries, generating positive co-movement between countries has proved to be quite hard in the context of real international business cycle models (IRBC henceforth).[1] This issue has been at the heart of research in two country real business cycle models since the seminal work of Backus, Kehoe and Kydland (1992) (BKK henceforth). In the absence of endogenous mechanisms that would generate international co-movement, these models typically rely on correlated total factor productivity shocks to deliver this co-movement. While it is relatively easy to generate co-movement in output and consumption using correlated shocks, it is quite difficult to do so for investment. Indeed, the prototypical IRBC model will generate large negative cross-country correlations of investment. The goal of this paper is to write down a simple modification of the canonical two-country, one-good international real business cycle model that can solve this problem.

Before turning to our model, we briefly discuss existing attempts at resolution and why success has been limited for the most part. The reason this occurs is because negative co-movement in investment is built into the heart of the canonical model and is therefore difficult to overcome. To see this, consider a positive shock to productivity in the home country that raises the relative return to capital in that country. The ensuing increase in investment in the home country is financed partially by domestic means as well as by resources which flow in from the foreign country. At the same time, investment is relatively less attractive in the foreign country so agents reduce foreign investment below steady-state levels and we end up with highly negative co-

[1] Evidence can be found in Ambler, Cardia and Zimmermann (2004) who compare 190 country pairs and find that cross-country correlations of output, consumption, investment and hours are positive on average. Moreover, they find that the cross-country correlations of investment and hours are positive for at least seventy-five percent of the 190 pairs.

movement in investment between the two countries.

Since the early work of BKK, a large number of modifications of the canonical model have been proposed to ameliorate this, and other discrepancies between the implications of the model and the actual features of the data. We focus here on the small, but growing, set of articles that actually **succeed** in delivering positive investment correlations by modifying the standard IRBC model in various ways. A common feature of these models is that they achieve a positive investment correlation between countries at the expense of a fall in the relative volatility of investment. In the data, the HP filtered standard deviation of investment is approximately three times as volatile as output. None of these studies are able to simultaneously deliver realistic international correlations of investment as well as sufficiently volatile investment. It would appear there is a trade-off between the two moments in the basic structure of the model. This trade-off is clearly visible in the simulation results of Baxter and Farr (2005), Ravn and Mazzenga (2004) or Heathcote and Perri (2002). A quick look at Table 2 (pp. 344) of Baxter and Farr reveals that the cross-country correlation of investment rises while the relative volatility of investment falls as one goes from case 1 to case 3. Similar patterns can be found in Canova and Ubide (1998), Kehoe and Perri (2002), Ambler *et al* (2002) as well as in Corsetti *et al* (2008).[2]

The above pattern is not accidental. Any mechanism designed to slow down the flow of resources across countries will likely also reduce the amount of investment that can be financed by the country where productivity is relatively high. This will lead to a fall in the volatility of investment at the same time that its international investment correlation increases. This idea is illustrated in Figure 1a for a one-good model where we plot the volatility of investment against its cross-country correlation while varying a capital adjustment cost parameter. This is done in a standard IRBC model with

[2]Two exceptions are Cook (2002) and Head (2002).

incomplete asset markets.[3] Not only is the aforementioned trade-off between the two moments clearly visible, it is also apparent that even the most basic two country model can generate a positive cross-country investment correlation if one is willing to tolerate sufficiently low investment volatility.

Our reading of the literature leads us to conclude that while progress has been made in accounting for the observed international co-movement of investment, current explanations remain partial and unsatisfactory in that they cannot simultaneously account for the observed volatility of investment. Suitably calibrated two-good models, as well as models with multiple shocks, help to reduce the discrepancy between model and data but are not able to eliminate it.[4] We return to Figure 1a to explain this point. The figure reveals that the trade-off discussed above is quite potent, in that, even minor reductions in volatility can lead to big increases in the correlation in percentage terms. For example, decreasing the relative volatility of investment from roughly 2.7 to just 2.4 leads to a movement in the international correlation from roughly -0.1 to 0.1, a move of two hundred percent. Given this sensitivity, it is important to control the volatility of investment wherever possible before evaluating any movements in its international correlation, as we will do.

Is it possible to stay close to the spirit of the canonical model and simultaneously generate realistic international co-movement as well as volatility? In this paper we answer the above question in the affirmative. This goal is achieved by modifying the technological environment in which firms operate. The novel element is a new input (in addition to labour and physical capital) which we refer to as organizational capital.

[3] The cross-country correlations of shocks is set at 0.323.

[4] Pakko (2003) highlights the role of low substitution elasticities in a two-good version of the model in generating a positive international correlation for investment. Once again, this is only achieved via a drastic reduction in investment volatility. A similar problem plagues Dotsey and Duarte (2008) which stresses the role of non-traded goods in a monetary model with an interest rate rule and real shocks.

Organizational capital (OC) may be thought of in terms of knowledge or ideas related to the process of production that help determine how much output results from the application of conventional inputs in the context of a particular technology. We think of OC as being a key determinant of the endogenous component of productivity, something that is co-produced by firms in the process of creating output. The idea that firm's are store-houses of OC can be found in Prescott and Vischer (1980) and more recently in Atkeson and Kehoe (2005) who measure the value of OC in the US economy and find that it is roughly half the size of the physical capital stock. Hou and Johri (2008) show that a model with OC fits aggregate US data significantly better than a standard DSGE model. Moreover, the model does a better job of capturing the dynamic responses of the US economy to various shocks.

We think that the presence of OC may be a useful way to model the reasons why firms may not wish to transfer capital internationally with the same ease and intensity as implied by the typical two country model in response to transitory productivity shocks. In the real world, moving capital can lead to the permanent loss of firm specific knowledge and skills embodied in workers and managers.[5] These losses would have an impact on productivity which can only be made up slowly over time. While the canonical model allows for costs to adjusting the capital stock, it does not take into account these potential productivity losses. The introduction of OC into the production technology is an attempt to try to take into account these additional considerations in the simple aggregate context of a one-good model.

Organizational capital is modeled following the learning-by-doing (LBD) specification used in Cooper and Johri (2002), in which agents accumulate OC as a by-product of past output. A crucial (and empirically important) feature of this specification is that OC created in the past makes a diminishing contribution to the creation of

[5] Or this knowledge may reside in the match between worker and capital or in a team. The dissolution of these matches or teams may lead to a loss of information and productivity.

future levels of OC. As a result, reductions in current output lead to a reduction in future levels of OC which imply a fall in productivity. Since physical capital is used to produce output, a current reduction in investment leads to a future fall in capital and consequently a future fall in productivity. Realizing this dynamic linkage between investment decisions and future productivity levels, agents in the foreign country are loath to reduce investment in response to a home-country productivity shock. Organizational capital also acts as a magnification device leading to an increased volatility in home country variables. The trade-off between international co-movement and investment volatility mentioned above is present in our model as well, however, the OC model generates higher investment correlations for each level of investment volatility. As can be seen in Figure 1b, the introduction of OC is equivalent to an upward shift in the trade-off plot shown in Figure 1a.

We now provide a brief discussion of the relevance of learning-by-doing and especially of our specification of OC. There is a large empirical literature documenting the pervasive influence of learning-by-doing in productive activities dating back a hundred years. Recent micro-economic studies include Benkard (2000), Thompson (2001), Thornton and Thompson (2001) and Clarke (2006). Cooper and Johri (2002) provide 2-digit and 4-digit evidence for the U.S. manufacturing sector. Aggregate evidence from the U.S. for the specific form of learning used here can be found in Johri and Letendre (2007) and Hou and Johri (2008). These studies find that agents and organizations appear to become more productive as they gain experience at producing a particular product or service. A number of these studies also report spillover effects in learning across similar products, both within and across firms. We ignore these effects in order to focus on the mechanism described above.

Our model builds on the closed economy framework of Cooper and Johri which is inspired by the early work of Arrow (1962) and especially Rosen (1972) on learning as a by-product of production. In the dynamic general equilibrium literature, learning-by-doing and OC has been used mainly in closed economy contexts (Cooper and Johri 2002, Clarke and Johri 2009, Johri 2009 and Gunn and Johri 2010). In open-economy models it has been shown to help generate persistent movements in the real exchange rate (Johri and Lahiri 2008) in response to monetary shocks.

In order to deliver international co-movement in all major aggregate variables without sacrificing realism in the relative volatility of investment, we adopt two other modifications of the one-good, two-country canonical model from the literature. These are the presence of incomplete asset markets of the kind discussed in Baxter and Crucini (1995) and the use of preferences associated with the work of Greenwood, Hercowitz and Huffman (1988), GHH henceforth. We show that this model, calibrated to US data, can deliver all the key features of international co-movement discussed above. In particular the cross-country correlations of consumption, output, hours as well as investment are all positive. The role of GHH preferences is to make the cross-country correlation of hours positive as in Raffo (2008) while incomplete markets lowers the cross-country correlation of consumption.

The key feature of GHH preferences is that the income effect of a change in productivity on hours is absent. As a result, hours in both countries closely follow movements in productivity. Since productivity shocks are correlated, so are hours. GHH preferences are commonly used in the open-economy literature dating back to Devereux, Gregory and Smith (1992). See Letendre (2004), Letendre and Luo (2007), Raffo (2008) and Boileau and Normandin (2008a) for some recent examples.

The paper is organized as follows. Section 2 presents our two-country model. Section 3 explains how we solve the model and select parameter values. Section 4 analyzes the dynamic properties of our model. Section 5 discusses the moments implied by our model and Section 6 offers some concluding remarks.

2. Model

Our economy is composed of two countries labeled "the home country" and "the foreign country". Each country is inhabited by a large number of infinitely lived identical agents. Both countries produce a homogeneous final good which may be used either for consumption or for investment. The final good can be traded freely across the two countries, but trade in financial assets is restricted to a simple non-contingent real bond. We denote all foreign country variables with an asterisk.

The representative agent in the home country seeks to maximize his expected lifetime utility given by:

$$\mathcal{U} = E_0 \sum_{t=0}^{\infty} \beta^t U(C_t, N_t), \qquad 1 > \beta > 0 \tag{1}$$

where the period utility function has the GHH form

$$U(C_t, n_t) = \frac{[C_t - \psi N_t^{\nu}]^{1-\sigma}}{1-\sigma}, \qquad \psi > 0,\ \nu > 1,\ \sigma > 0 \tag{2}$$

where E_t denotes the mathematical expectation operator conditional on the agent's time t information set, C_t denotes consumption, N_t denotes hours worked, β is a discount factor, σ is the coefficient of relative risk aversion, ν determines the Frisch labour supply elasticity and ψ determines the relative weight of consumption and leisure.

Output in the home country (Y) is produced using labour (N), physical capital (K), and organizational capital (H)

$$Y_t = A_t H_t^{\varepsilon} K_t^{1-\alpha-\varepsilon} N_t^{\alpha}, \qquad 0 < \varepsilon, \alpha < 1, \tag{3}$$

where A_t is a stationary productivity shock. Since we are focusing on movements at the business cycle frequency we ignore technical progress of any form.

The technology differs from the standard neo-classical production function (used in the model without OC) because the agent carries a stock of organizational capital which is an input in the production technology. Organizational capital refers to the information accumulated by the agent, through a learning process involving past production, regarding how best to organize his production activities and combine inputs. As a result, the higher the level of organizational capital, the more productive the agent. Note that there are diminishing returns to accumulating organizational capital, a feature often found in empirical studies of learning-by-doing.

There are at least two ways to think about what constitutes organizational capital. Some, like Rosen (1972), think of it as a firm specific capital good while others focus on specific knowledge embodied in the matches between workers and tasks or machines within the firm. While these differences are important, especially when trying to measure the payments associated with various inputs, they are not crucial to the issues at hand which involve the loss of these forms of knowledge as a result of disinvestment. As a result we do not distinguish between the two.

The exact specification of how learning-by-doing leads to productivity increases can be found in Cooper and Johri (2002) which draws on early work by Arrow (1962) and Rosen (1972). Learning is modeled through an accumulation equation for organizational capital which is closely related to the empirical learning-by-doing literature in which each cumulative unit of past production contributes equally to the creation of knowledge. Recent studies include Bahk and Gort (1993), Irwin and Klenow (1994), Jarmin (1994), Thompson (2001) and Thornton and Thompson (2001). Our specification differs from the typical one, in that the contribution of production in any period to the current level of organizational capital is decreasing over time. Following Cooper and Johri (2002), who provide evidence on this specification, we write the accumulation technology as

$$H_{t+1} = H_t^{\gamma} Y_t^{1-\gamma}, \qquad 0 < \gamma < 1 \tag{4}$$

where H_t denotes the stock of organizational capital available to the agent at time t.

H_0 denotes the initial endowment of organizational capital which must be positive.

This modification of the traditional specification of learning has a number of advantages. First, it allows for the sensible idea that production knowledge may become less and less relevant over time as new techniques of production and management, new product lines, new workers and new markets emerge. Second, it allows in a general way for the idea that some match specific knowledge may be lost to firms in the economy as workers leave or get reassigned to new tasks or teams within the firm. In addition, the knowledge accumulated through production experience will be a function of the current vintage of physical capital. The decision to replace physical capital will imply that the existing stock of organizational capital will be less relevant. Third, it allows for the existence of a steady state in which the stock of organizational capital is constant. In contrast, the traditional specification in the empirical learning-by-doing literature allows the stock of organizational capital to grow unboundedly. An alternative way to bound OC is to assume that productivity increases due to OC occur for a fixed number of periods. While this may be appropriate for any one task or worker within the economy, we think of the economy as a whole as an environment with an ever changing set of tasks, workers, teams, machines and information. In this context it may be better to model organizational capital as continually accumulating and depreciating.

The restriction $\gamma < 1$ is consistent with the empirical evidence supporting the hypothesis of depreciation of organizational capital often referred to as organizational forgetting. Argote *et al.* (1990) provide empirical evidence for this hypothesis of organizational forgetting associated with the construction of Liberty Ships during World War II. Similarly, Darr *et al.* (1995) provide evidence for this hypothesis for pizza franchises and Benkard (2000) provides evidence for organizational forgetting associated with the production of commercial aircraft. One difference between these studies and this paper is that the accumulation technology is log-linear rather than linear. Clarke (2006) shows that the additional curvature in this log-linear technology produces similar predictions for aggregate variables in a closed economy context. We expect similar results to follow in the current context[6].

The accumulation equation for the stock of physical capital in the home country is

$$K_{t+1} = (1-\delta)K_t + I_t - \frac{\phi}{2}\left(\frac{I_t}{K_t} - \delta\right)^2 K_t, \qquad 0 \leq \phi,\ 0 < \delta < 1 \tag{5}$$

where I_t denotes investment made in the home country and δ is the depreciation rate of physical capital. The accumulation equations for the stock of physical capital (5) and (7) include capital adjustment costs, which are governed by the parameter ϕ, to smooth investment movements. The adjustment costs function is set in such a way that the model with adjustment costs has the same steady state as the model without them.

For the foreign country, output is given by:

$$Y_t^* = A_t^* H_t^{*\varepsilon} K_t^{*1-\alpha-\varepsilon} N_t^{*\alpha}, \qquad 0 < \varepsilon, \alpha < 1 \tag{6}$$

and the capital accumulation equation is

$$K_{t+1}^* = (1-\delta)K_t^* + I_t^* - \frac{\phi}{2}\left(\frac{I_t^*}{K_t^*} - \delta\right)^2 K_t^*. \tag{7}$$

Similarly organizational capital in the foreign country is accumulated via

$$H_{t+1}^* = H_t^{*\gamma} Y_t^{*1-\gamma}, \qquad 0 < \gamma < 1. \tag{8}$$

The exogenous process for the productivity shocks is a bivariate autoregressive process (in logs):

$$\begin{bmatrix} \ln A_{t+1} \\ \ln A_{t+1}^* \end{bmatrix} = \begin{bmatrix} \rho & \upsilon^* \\ \upsilon & \rho^* \end{bmatrix} \begin{bmatrix} \ln A_t \\ \ln A_t^* \end{bmatrix} + \begin{bmatrix} \epsilon_{t+1} \\ \epsilon_{t+1}^* \end{bmatrix}, \qquad E[\epsilon\epsilon^\top] = \sigma_\epsilon^2 \begin{bmatrix} 1 & \tau \\ \tau & 1 \end{bmatrix} \tag{9}$$

[6] Another seemingly crucial feature of our model is that organizational capital is accumulated as a by-product of production. This ignores the considerable intentional investments made by firms in raising productivity. Hou and Johri (2008) show that allowing for intentional investments in organizational capital result in only small differences from the Cooper and Johri (2002) model.

where ρ and ρ^* measure the persistence of domestic and foreign productivity shocks, υ and υ^* measure the degree of spillovers across countries, σ_ϵ^2 denotes the variance of innovation ϵ and τ denotes the cross-country correlation of innovations.

The financial markets in our world economy are incomplete. More specifically, only one-period risk-free real bonds can be traded. These bonds are traded at price $P_t = (1 + r_{t+1})^{-1}$, where r_{t+1} is the domestic real return on bonds purchased in period t. That is, r_{t+1} is the interest rate linking periods t and $t+1$. We denote the quantity of discount bonds purchased by residents of the home country in period t by B_{t+1} (each paying one unit of consumption in period $t+1$). The budget constraint for the representative agent in the home country is

$$C_t + I_t + P_t B_{t+1} = Y_t + B_t. \tag{10}$$

The budget constraint for the foreign country agent is

$$C_t^* + I_t^* + P_t^* B_{t+1}^* = Y_t^* + B_t^*. \tag{11}$$

We assume that bonds are in zero net supply, so bond market clearing requires

$$B_t + B_t^* = 0. \tag{12}$$

Following Devereux and Smith (2007) we assume there are some frictions in the bond market that create an interest rate differential across countries. Formally we assume

$$1 + r_{t+1} = (1 + r_{t+1}^*)\; e^{-\chi[B_{t+1} - \bar{b}]}, \qquad \chi > 0 \tag{13}$$

where r_t^* is the foreign real interest rate and $\bar{b}$ denotes bond holdings of the home country in steady state. The "premium" $e^{-\chi[b_{t+1} - \bar{b}]}$ appearing in (13) implies that the further in debt the domestic country gets (the more negative B becomes) the higher the interest rate at home compared to the foreign country. The bond price version of equation (13) is

$$P_t^* = P_t\; e^{-\chi[b_{t+1} - \bar{b}]}.$$

Technically, we need a mechanism to deal with the existence of a unit root in bond accumulation in the incomplete markets economy and our "risk premium" is one way to make the model stationary (see Boileau and Normandin (2008b) for more on this issue).

3. Model Solution and Parameter Values

An approximate linear solution to our model is obtained using the method outlined in King, Plosser and Rebelo (2002). See the Appendix for the first-order conditions and details about how we solve the model (and a special case of it without OC). The KPR method requires us to assign values to the model's parameters. Except for the values associated with OC most of the parameter values used in our work are commonly found in the business cycle and international macro literature. We now explain how we assign values to the parameters in our international business cycle model with OC (Table 1 provides a summary of our parameter values).

The reference period is a quarter. Following the IRBC literature we set the coefficient of relative risk aversion, σ, to 2. We let ψ adjust so that the fraction of time spent working in steady state is equal to 0.3. The remaining preference parameter ν is set to 3 so that the Frisch labour supply elasticity has a value of 0.5 which is near the middle of the range of micro estimates. We set the discount factor β to 0.993 a common value in the RBC literature (see Burnside and Eichenbaum (1996) among others).

The United States net foreign asset position has dramatically changed since the early 1980s. From the 1950s to the early 1980s, the position (as a percentage of output) was around 10% (see for example Masson *et al* 1994). It has since plunged to around negative 20% (see for example Gourinchas and Rey (2007)). The average over the period 1975-2005 is close to zero (-0.03). Accordingly, we set $\bar{b} = 0$ which implies zero net foreign asset holding in steady state.

An estimate of χ can be found in Lane and Milesi-Ferretti (2001): $\chi = 0.001$.

The capital adjustment cost parameter ϕ is set to produce a realistic investment volatility relative to the volatility of output. While the exact number for this relative volatility varies slightly from one paper to the next, it is normally around 3 for US data detrended with the Hodrick-Prescott or band-pass filters. For example, BKK (1995) report a relative investment volatility of 3.27, Baxter and Farr (2005) report 2.98, and Chari, Kehoe and McGrattan (2005) report 2.78. Accordingly, we set ϕ so that the model produces a relative standard deviation of investment of 3.

For the technology parameters, we use the values $\alpha = 0.55$, $\varepsilon = 0.24$, $\delta = 0.02$, and $\gamma = 0.95$ estimated by Johri and Letendre (2007) using aggregate US data. These values imply a capital-output ratio of 9.8 and a labour share of 0.7. Also, the value $\varepsilon = 0.24$ implies an eighteen percent learning rate which is fairly conservative.

Finally we discuss the parameters related to the technology shocks. The variance of the innovations σ_ϵ^2 is adjusted so that each model matches the standard deviation of output in the data. Again, this value varies across papers for US data. For example, BKK (1995) report a value of 1.92, Baxter and Farr (2005) report 1.69, and Chari, Kehoe and McGrattan (2005) report 1.82. The latter number is in the middle of the pack so we set σ_ϵ^2 to match it. International spillovers are not estimated precisely (see for example BKK (1992)) so we follow Baxter and Crucini (1995), Baxter and Farr (2005) and Kehoe and Perri (2002) (to name a few) and set $\upsilon = \upsilon^* = 0$.

For the cross-country correlation of shocks we use a recent estimate of $corr(\epsilon, \epsilon^*) = 0.323$ calculated by Boileau and Normandin (2008b). Their estimate is slightly larger than the estimate of 0.258 initially found by Backus *et al* (1992). This is understand-able since BKK allowed the shocks process to have non-zero international spillovers when estimating $corr(\epsilon, \epsilon^*)$. Given that our process has zero spillovers we think that Boileau and Normandin's estimate, which was computed imposing zero spillovers, is a more appropriate number. Accordingly we set $corr(\epsilon, \epsilon^*) = 0.323$.

We follow Kollmann (1996), Kehoe and Perri (2002) and others and set the persistence of the Solow residual to 0.95. Note that in our model the Solow residual is endogenous and is given (in logs) by $\ln A + \varepsilon \ln H$. When OC is not included in the model, the Solow residual is entirely exogenous and is equal to $\ln A$. Since OC generates some endogenous persistence in the Solow residual we actually use a slightly lower ρ in the OC model ($\rho = 0.945$) than in the no-OC model ($\rho = 0.95$) so that the autocorrelation of the Solow residual is the same in both models. Note that the cross-country correlation of the Solow residuals is the same (0.32) in the OC and no-OC models so we use $corr(\epsilon, \epsilon^*) = 0.323$ in both models.

4. Dynamics of the model

In this section we discuss the economics of our model in the context of impulse responses to technology shocks which can be found in Figures 2 and 3. To calculate impulse response functions (IRFs) we simulate the model while feeding it the following matrix of innovations

$$\begin{bmatrix} \epsilon_t \\ \epsilon_t^* \end{bmatrix}_{t=1}^{\infty} = \begin{bmatrix} 0.01 & 0 & 0 & 0 & \dots \\ 0.01\ corr(\epsilon,\ \epsilon^*) & 0 & 0 & 0 & \dots \end{bmatrix}. \tag{14}$$

That is, the home country experiences a one percent positive shock and the foreign country simultaneously experiences a shock of size $0.01 \times corr(\epsilon,\ \epsilon^*)$. We look at the responses of both the models with and without OC for two separate cases, one where $corr(\epsilon,\ \epsilon^*) = 0.323$ and another where $corr(\epsilon,\ \epsilon^*) = 0$.

4.1 Investment Dynamics

4.1.1 Model without Organizational Capital

Figure 2 plots the response of investment for both countries in the calibrated versions of our model (labeled I OC and I^* OC) and its no-OC version (labeled I and I^*). The impact of organizational capital is clearly visible in the figure, especially for the dynamics of investment in the foreign country. While I^* falls below steady state on impact, I^* OC rises and stays above steady state for a number of periods. Recall that the path of foreign country investment in this figure is jointly determined by the exogenous movement in technology, A^* (due to the presence of correlated shocks) and the endogenous response of the foreign country agent to the home country shock. In order to isolate the impact of organizational capital on the dynamics of the model, we wish to switch off the former effect. As a result, in Figure 3, we study the case of uncorrelated shocks where A^* remains at steady state levels throughout the exercise.We also impose the same value of ϕ (namely $\phi = 2.76$) on both models so that this is no longer a source of variation between the responses of the two models.

Figure 3 emphasises the different responses of the foreign agent to the domestic shock across the two models. In the model without organizational capital, investment falls in the foreign country and stays below steady state for roughly ten quarters. The presence of organizational capital cuts the negative response of the foreign agent by about half on impact and shortens the time spent below steady state to about five quarters. Comparatively speaking, the response of the domestic agent is similar in the two models, though there is some evidence of magnification in the OC model. In order to analyze these differential responses in Figure 3, we will study the two models in turn, starting with the no-OC model. We will end the discussion with a brief comment on the additional impact of the exogenous shocks in Figure 2.

In order to explain why investment behaves differently in the two countries we look at the capital first-order conditions abstracting from adjustment costs.

$$1 = E_t \beta \frac{\lambda_{1t+1}}{\lambda_{1t}} \left\{ \frac{(1-\alpha) A_{t+1} {N_{t+1}}^{\alpha}}{[(1-\delta)K_t + I_t]^{\alpha}} + 1 - \delta \right\} \quad (15)$$

$$1 = E_t \beta \frac{\lambda^*_{1t+1}}{\lambda^*_{1t}} \left\{ \frac{(1-\alpha) A^*_{t+1} {N^*_{t+1}}^{\alpha}}{[(1-\delta)K^*_t + I^*_t]^{\alpha}} + 1 - \delta \right\} \quad (16)$$

A glance at (15) and (16) reveals that the response of investment is governed by two factors which we discuss in turn. The first factor is the expression within braces which captures the return to capital accumulation. The second factor is the marginal rate of substitution between consumption in periods t and $t+1$ given by MRS $\equiv \beta\lambda_{1t+1}/\lambda_{1t}$.

In the impact period of the shock, since capital is predetermined, the return on capital for a given level of investment is governed mainly by A_{t+1} directly and indirectly through its effect on N_{t+1}. As we will discuss below, hours will rise in the home country so that the return to accumulating capital rises. On its own, this would cause the home country agent to increase investment. This desire to invest is somewhat dampened by a small fall in the MRS as consumption rises slowly. Due to the desire to smooth consumption, the MRS changes only by a small amount in response to the shock. The small drop in MRS is dominated by the large and persistent technology shock which raises the marginal product of capital. The rise in hours accentuates this increase. To satisfy the Euler equation (15), investment must increase in the home country and stay above steady state until the persistent effects on the productivity of capital slowly wear off.

The analysis of the response of the foreign agent uses the same elements as above but is simplified by the absence of any exogenous movement in productivity since we are studying the uncorrelated shock case in Figure 3. Anticipating the analysis of the next section, since the response of N^* (which is governed by A^* and K^*) is zero on impact and extremely small in the period after the shock, there is hardly any movement in the return to capital. As a result, the drop in I^* can be understood mostly by the movement in MRS*. Why does MRS* fall when productivity rises in the home country? Recall that the two countries are linked together by trade in bonds. The Euler equation for bonds in the foreign country implies

$$P_t^* = E_t \beta \frac{\lambda_{1t+1}^*}{\lambda_{1t}^*} \tag{17}$$

The persistent positive shock in the home country creates a desire for an increase in investment and consumption there. In a closed economy, either the desire for increased consumption must be tempered or leisure sacrificed in order to satisfy the desire for more capital. Both of these responses reduce utility and dampen the increase in investment. In an open economy, however, there exists an alternative avenue to finance investment: acquiring resources from the other country. In our model environment, the home country can finance some of its investment through international borrowing by selling bonds to the foreign country. For the bond market to clear, the additional supply of bonds must result in a fall in their price below steady state. The Euler equation (17) implies that the fall in P^* must be accompanied by a fall in MRS*. In other words the return to bonds must rise above its steady state value in order to induce the foreign agent to postpone his consumption. This allocative signal also induces the observed fall in investment in the foreign country.

When shocks are correlated across countries, the price of bonds must fall even more because the small shock experienced by the foreign country raises the return to investment and, everything else equal, makes the foreign agent also interested in borrowing to invest. Since the home shock is much bigger, and the home country's desire to borrow much greater, the bond price must fall even more than in the zero-correlation scenario to convince the foreign country to lend to the home country.

4.1.2 Model with Organizational Capital

We now turn to the response of investment in our model with OC in Figure 3 which will be followed by a short discussion of the case depicted in Figure 2 with correlated shocks. The focus of our discussion will be the differential response of investment in the foreign country relative to the model without OC discussed above. In order to understand why the drop in investment in the foreign country is so much smaller than in the no-OC model we turn to the appropriate Euler equations abstracting once more from adjustment costs. These can now be written as

$$1 = E_t\beta\left\{\frac{\lambda_{1t+1}}{\lambda_{1t}}\left(\frac{(1-\alpha-\varepsilon)A_{t+1}{N_{t+1}}^{\alpha}H_{t+1}^{\varepsilon}}{[(1-\delta)K_t+I_t]^{\alpha+\varepsilon}}+1-\delta\right)+\frac{\lambda_{3t+1}}{\lambda_{1t}}\frac{(1-\alpha-\varepsilon)(1-\gamma)H_{t+2}}{[(1-\delta)K_t+I_t]}\right\} \tag{18}$$

$$1 = E_t\beta\left\{\frac{\lambda_{1t+1}^{*}}{\lambda_{1t}^{*}}\left(\frac{(1-\alpha-\varepsilon)A_{t+1}^{*}{N_{t+1}^{*}}^{\alpha}{H_{t+1}^{*}}^{\varepsilon}}{[(1-\delta)K_t^{*}+I_t^{*}]^{\alpha+\varepsilon}}+1-\delta\right)+\frac{\lambda_{3t+1}^{*}}{\lambda_{1t}^{*}}\frac{(1-\alpha-\varepsilon)(1-\gamma)H_{t+2}^{*}}{[(1-\delta)K_t^{*}+I_t^{*}]}\right\} \tag{19}$$

for the home and foreign countries respectively.

Given the similarities of the two models, the impact of bond prices and the marginal product of capital on the behavior of investment is relatively similar and not surprising. Comparing the capital Euler equation in the no-OC model (16) with (19) shows that the first term inside braces in (19) is very similar to the expression on the right side of (16). Once again, the fall in bond prices dominate any small changes in the marginal product of capital. Therefore, the foreign agent is induced to postpone consumption, buy home country bonds and reduce investment. This effect is mitigated by the presence of a new term appearing in the capital Euler equation. This term captures the value of time $t+2$ organizational capital that is induced by the extra output created by having an additional unit of physical capital in $t+1$ and reflects the fact that agents internalize this link between investment in period t and the amount of organizational capital available in $t+2$. Should we expect this effect to moderate the desire of the foreign agent to reduce I_t^*? The answer lies in the signal sent by the relative price (value) of organizational capital to the consumption good. This price is captured in the ratio of Lagrange multipliers $\lambda^*_{3t+1}/\lambda^*_{1t}$ in (19) which represents the value of an additional unit of H^*_{t+2} in terms of current consumption. One might expect that this price will rise as future quantities of organizational capital become relatively scarce as can indeed be seen in Figure 4. On its own, this rise in the relative price of future organizational capital induces the agent to try to accumulate more of the scarce factor. Overall, it acts as a countervailing force to the strong incentives coming from the home country via the fall in bond prices. This results in a smaller drop in investment on impact as well as a shorter duration of time spent below steady state investment levels.

Turning from Figure 3 to Figure 2, the main difference is that the foreign country now also receives a small shock which raises the marginal product of capital. The foreign agent now has an additional incentive to increase investment which is sufficient to make its investment response positive.

4.2 Hours Dynamics

Since the effect of GHH preferences on the behaviour of hours is relatively well understood, we only provide a short discussion without any figures of what to expect from the two models. To understand the role of GHH preferences it is useful to compare the first-order condition for hours in our no-OC model and a variant of it where the periodic utility function takes the iso-elastic form

$$U(C_t, n_t) = \frac{\left[C_t^{\psi}(1-N_t)^{1-\psi}\right]^{1-\sigma}}{1-\sigma}, \qquad 1 > \psi > 0,\ \sigma > 0 \tag{20}$$

instead of the GHH form in (2).

The hours first-order condition of the no-OC model with preferences (20) is given below. It equates the marginal disutility of working an extra hour with the marginal utility gain from the extra output produced. An equivalent condition for the foreign country is suppressed.

$$\frac{1-\psi}{1-N_t} = \alpha \frac{\psi}{C_t} \frac{Y_t}{N_t} \tag{21}$$

Recall that a weakly correlated productivity shock raises the marginal product of labour in both countries. On it's own, this encourages both countries to raise hours above steady state. With standard preferences the increase in consumption fueled by the wealth effect, however, tends to dampen the desire to increase hours. In the home country the former dominates the latter but in the foreign country the relatively weak productivity shock is overshadowed by the wealth effect resulting in hours falling quickly.

With GHH preferences, the wealth effect is eliminated. As a result only the substitution effect operates on hours as can be seen from the hours first-order condition.

$$\psi \nu N_t^{\nu-1} = \alpha \frac{Y_t}{N_t} \tag{22}$$

This suggests that hours and labour productivity will move together in both countries. Linearizing the above condition and the production function yields $(\nu - \alpha)\hat{N}_t = \hat{A}_t + (1-\alpha)\hat{K}_t$ where a "hat" denotes a variable in percent deviation from its steady state (*e.g.* $\hat{N}_t \equiv (N_t - \bar{N})/\bar{N}$). Given the typical smoothness in the response of the stock of physical capital, the linearized condition shows that hours are largely driven by technology shocks (entirely in the first period). Therefore, the positive comovement in hours across countries is a reflection of the positive cross-country correlation of shocks.

We now turn to the OC model where the first-order condition for hours is given by

$$\psi \nu N_t^{\nu-1} = \alpha \frac{Y_t}{N_t}[1 + \frac{\lambda_{3t}}{\lambda_{1t}}(1-\gamma)H_t^{\gamma} Y_t^{-\gamma}] \tag{23}$$

where λ_1 and λ_3 are Lagrange multipliers associated with the budget constraint and the accumulation equation for organizational capital respectively. Relative to (22), this condition has a second term because the agent realizes that working an extra hour will yield additional organizational capital in the future. This organizational capital has a marginal value equal to λ_{3t}. Additional organizational capital is valued by the agent not only because it is an input in the production technology but also because it is an input in the learning process, contributing to the further accumulation of organizational capital. This can be seen in the first-order condition associated with organizational capital:

$$\lambda_{3t} = \beta E_t \left\{ \varepsilon \lambda_{1t+1} \frac{Y_{t+1}}{H_{t+1}} + (\gamma + \varepsilon(1-\gamma))\lambda_{3t+1} H_{t+1}^{\gamma-1} Y_{t+1}^{1-\gamma} \right\}. \tag{24}$$

The first term on the right captures the utility value of the extra production in period $t+1$ while the second term captures the value of the additional future organizational capital. As highlighted in section 4.1.2 the foreign agent values his stock of organizational capital and behaves in a way to limit its fall. Limiting the fall in I^* is one way to achieve this objective, so is working a little harder. In the no-OC model hours worked N^* fall when a shock hits the home country only (correlation switched off) whereas they increase in the OC model. However, for our parametrization, the difference in the response of N^* across models is very small.

Based on the responses of the models with and without OC, it would appear that GHH preferences mainly influence the dynamics of hours while OC influences the dynamics of investment. We now turn to a calculation of second moments to see if these changes are sufficient to deliver positive international correlations in all key aggregate variables.

5. Moments

In this section we discuss the usual second moments for our model and the variant without OC which are compiled in Table 2. Table 3 provides results from our sensitivity analysis as we vary key parameters.

The first column of numbers in Table 2 corresponds to the data[7] while the second column corresponds to our model.[8] In the first column, we see that the cross-country correlation of consumption, hours, investment and output are all positive. In their comprehensive study of cross-country correlations Ambler *et al* (2004) conclude that "A remarkable common feature emerges: these correlations are mostly positive, not very high and of a similar order of magnitude." As the second column of numbers shows, our model accords with their conclusion.

In order to highlight the impact of OC we report the results of the no-OC model in the third column of numbers. We need to alter ϕ to ensure the relative volatility of investment is still at 3.[9] Similarly we need to raise ρ to 0.95 to ensure the autocorrelation of the Solow residual is the same in both models. Finally we raise the share of physical capital in the production technology in order to maintain constant returns to scale once organizational capital is removed.

Removing OC from the model has a big impact on the investment correlation which turns sharply negative as suggested by the impulse responses discussed in section 4. Other international correlations also fall a little but remain positive. There is no dramatic change in the relative standard deviation of consumption and hours. Since OC affects investment dynamics, we also report the first-order autocorrelation of investment which increases only slightly. Both models are consistent with the fact that output is negatively correlated with the trade balance-output ratio and they

[7]Numbers in the "Data" column are ranges constructed using the statistics reported by BKK (1995), Chari, Kehoe and McGrattan (2002), and Baxter and Farr (2005).

[8]Artificial data are in percent deviations from steady state (except for the trade balance) and have been HP filtered. The moments reported are averages over 1000 replications. Each replication is 100 quarters long.

[9]In the no-OC model $\phi = 1.73$.

both struggle at matching the volatility of the latter. Correlations of consumption, hours and investment with output (not reported) are all large and positive in both models.

Table 3 reports the isolated effects of varying parameters on the cross-country investment correlation coefficient in our model with OC. Lowering β or raising σ as in Table 3 barely increase the co-movement of investment. The fifth column varies the relative weight of the two capital stocks in the production technology while the sixth column varies the weight of organizational capital and output in the accumulation technology. The last two columns lower the correlation of the shocks and the value of ν respectively. In all cases, the international correlation of investment is considerably higher than in the no-OC model and in all cases but one the correlation remains positive. This compares favorably to -0.38 in the no-OC model. We conclude from our sensitivity exercises that the ability of OC to improve the international investment correlation is quite robust.

6. Concluding Remarks

We take a standard international real business cycle model with incomplete markets and modify it in two ways by incorporating organizational capital and by using GHH preferences. GHH preferences help the model produce positive cross-country correlations of hours worked. Organizational capital has a large effect on the cross-country correlation of investment. By dampening the foreign country's willingness to reduce investment when the home country experiences a positive productivity shock, the model succeeds at producing a positive response of investment in both countries when the shocks are slightly correlated across countries. These changes in investment dynamics are sufficient to make the model predict a small positive cross-country correlation of investment while still matching the variance of investment relative to output.

7. Appendix

7.1 System of Equations—Model Described in Section 2

$$\lambda_{1t} = [C_t - \psi N_t^{\nu}]^{-\sigma} \tag{25}$$

$$\lambda_{1t}^{*} = [C_t^{*} - \psi N_t^{*\nu}]^{-\sigma} \tag{26}$$

$$\psi \nu N_t^{\nu-1} [C_t - \psi N_t^{\nu}]^{-\sigma} = \alpha \lambda_{1t} \frac{Y_t}{N_t} + \alpha(1-\gamma)\lambda_{3t} \frac{H_t^{\gamma} Y_t^{1-\gamma}}{N_t} \tag{27}$$

$$\psi \nu N_t^{*\nu-1} [C_t^{*} - \psi N_t^{*\nu}]^{-\sigma} = \alpha \lambda_{1t}^{*} \frac{Y_t^{*}}{N_t^{*}} + \alpha(1-\gamma)\lambda_{3t}^{*} \frac{H_t^{*\gamma} Y_t^{*1-\gamma}}{N_t^{*}} \tag{28}$$

$$\lambda_{1t} = \lambda_{2t} \left[1 - \phi \left(\frac{I_t}{K_t} - \delta\right)\right] \tag{29}$$

$$\lambda_{1t}^{*} = \lambda_{2t}^{*} \left[1 - \phi \left(\frac{I_t^{*}}{K_t^{*}} - \delta\right)\right] \tag{30}$$

$$\lambda_{2t} = \beta E_t \left\{ (1-\alpha-\varepsilon)\lambda_{1t+1} \frac{Y_{t+1}}{K_{t+1}} + \lambda_{2t+1} \left[1 - \delta + \phi \left(\frac{I_{t+1}}{K_{t+1}} - \delta\right) \frac{I_{t+1}}{K_{t+1}} - \frac{\phi}{2} \left(\frac{I_{t+1}}{K_{t+1}} - \delta\right)^2 \right] \dots \right.$$
$$\left. \dots + \lambda_{3t+1} \left[(1-\alpha-\varepsilon)(1-\gamma) \frac{H_{t+1}^{\gamma} Y_{t+1}^{1-\gamma}}{K_{t+1}} \right] \right\} \tag{31}$$

$$\lambda_{2t}^{*} = \beta E_t \left\{ (1-\alpha-\varepsilon)\lambda_{1t+1}^{*} \frac{Y_{t+1}^{*}}{K_{t+1}^{*}} + \lambda_{2t+1}^{*} \left[1 - \delta + \phi \left(\frac{I_{t+1}^{*}}{K_{t+1}^{*}} - \delta\right) \frac{I_{t+1}^{*}}{K_{t+1}^{*}} - \frac{\phi}{2} \left(\frac{I_{t+1}^{*}}{K_{t+1}^{*}} - \delta\right)^2 \right] \dots \right.$$
$$\left. \dots + \lambda_{3t+1}^{*} \left[(1-\alpha-\varepsilon)(1-\gamma) \frac{{H_{t+1}^{*}}^{\gamma} {Y_{t+1}^{*}}^{1-\gamma}}{K_{t+1}^{*}} \right] \right\} \tag{32}$$

$$\lambda_{3t} = \beta E_t \left\{ \varepsilon \lambda_{1t+1} \frac{Y_{t+1}}{H_{t+1}} + (\gamma + \varepsilon(1-\gamma)) \lambda_{3t+1} H_{t+1}^{\gamma-1} Y_{t+1}^{1-\gamma} \right\} \tag{33}$$

$$\lambda_{3t}^* = \beta E_t \left\{ \varepsilon \lambda_{1t+1}^* \frac{Y_{t+1}^*}{H_{t+1}^*} + (\gamma + \varepsilon(1-\gamma)) \lambda_{3t+1}^* {H_{t+1}^*}^{\gamma-1} {Y_{t+1}^*}^{1-\gamma} \right\} \tag{34}$$

$$P_t \lambda_{1t} = \beta E_t \lambda_{1t+1} \tag{35}$$

$$P_t^* \lambda_{1t}^* = \beta E_t \lambda_{1t+1}^* \tag{36}$$

$$C_t + I_t + P_t B_{t+1} = Y_t + B_t \tag{37}$$

$$C_t^* + I_t^* + P_t^* B_{t+1}^* = Y_t^* + B_t^* \tag{38}$$

$$K_{t+1} = (1-\delta) K_t + I_t - \frac{\phi}{2} \left(\frac{I_t}{K_t} - \delta \right)^2 K_t \tag{39}$$

$$K_{t+1}^* = (1-\delta) K_t^* + I_t^* - \frac{\phi}{2} \left(\frac{I_t^*}{K_t^*} - \delta \right)^2 K_t^* \tag{40}$$

$$H_{t+1} = H_t^{\gamma} Y_t^{1-\gamma} \tag{41}$$

$$H_{t+1}^* = H_t^{*\gamma} Y_t^{*1-\gamma} \tag{42}$$

$$Y_t = A_t H_t^{\varepsilon} K_t^{1-\alpha-\varepsilon} N_t^{\alpha} \tag{43}$$

$$Y_t^* = A_t^* H_t^{*\varepsilon} K_t^{*1-\alpha-\varepsilon} N_t^{*\alpha} \tag{44}$$

$$B_t + B_t^* = 0 \tag{45}$$

$$P_t^* = P_t \; e^{-\chi[B_{t+1}-\bar{b}]} \tag{46}$$

There are 22 endogenous variables: $C, N, Y, H, K, I, B, P, \lambda_1, \lambda_2, \lambda_3$ for both countries. There are 22 equations: (25) to (46). We assume $\bar{b} = 0$ (no asset holding in steady state) and use the fact that capital adjustment costs are zero in steady state. The steady state solution is presented below.

From (35) we get

$$P_{ss} = \beta. \tag{47}$$

Combining (29), (31), (33), and (41) we get

$$\left(\frac{Y}{K}\right)_{ss} = \frac{1-\beta(1-\delta)}{(1-\alpha-\varepsilon)\beta\left[1+\frac{1-\gamma\beta\varepsilon}{1-\beta(\gamma+\varepsilon(1-\gamma))}\right]} \tag{48}$$

Combining (41) and (43) we get

$$Y_{ss} = \left[\bar{A}\left(\frac{K}{Y}\right)_{ss}^{1-\alpha-\varepsilon} N_{ss}^{\alpha}\right]^{\frac{1}{1-\varepsilon(1-\gamma)/(1-\gamma)-(1-\alpha-\varepsilon)}}. \tag{49}$$

Using previously derived relations/equations we get

$$K_{ss} = Y_{ss}\left(\frac{K}{Y}\right)_{ss} \tag{50}$$

$$I_{ss} = \delta K_{ss} \tag{51}$$

$$H_{ss} = Y_{ss}. \tag{52}$$

Budget constraint (37) and $\bar{b} = 0$ imply

$$C_{ss} = Y_{ss} - I_{ss} \tag{53}$$

$$\psi^* = \frac{\alpha Y_{ss}}{\nu N_{ss}^{\nu}}\left(1+\frac{\beta\varepsilon(1-\gamma)}{1-\beta(\gamma+\varepsilon(1-\gamma))}\right) \tag{54}$$

$$\lambda_{1ss} = (C_{ss} - \psi N_{ss}^{\nu})^{-\sigma} \tag{55}$$

$$\lambda_{2ss} = \lambda_{1ss} \tag{56}$$

$$\lambda_{3ss} = \frac{\beta\varepsilon}{1-\beta(\gamma+\varepsilon(1-\gamma))}\lambda_{1ss}\frac{Y_{ss}}{H_{ss}} \tag{57}$$

The model will be solved using the KPR method. Note that adding up the two budget constraints and imposing bonds market clearing implies

$$C_t + C_t^* + I_t + I_t^* + B_{t+1}(P_t - P_t^*) = Y_t + Y_t^*$$

using (46) we get

$$C_t + C_t^* + I_t + I_t^* + B_{t+1}P_t(1 - e^{-\chi[B_{t+1}-\bar{b}]}) = Y_t + Y_t^*.$$

As long as we have a steady state bond holding of zero, the linearized version of the above equation is identical to the linearized version of the usual world resource constraint

$$C_t + C_t^* + I_t + I_t^* = Y_t + Y_t^*. \tag{58}$$

Recognizing that (linearized versions of) the two budget constraints (37) (38), the asset equilibrium condition (45) and the resource constraint (58) are not independent, we follow what Baxter and Crucini (1995) did when solving the model by KPR. (1) we drop the foreign budget constraint from the system and include the resource constraint, (2) we make the Lagrange multiplier associated with the home budget constraint a co-state variable. In addition, we simplify the system by eliminating prices P and P^* by using (35) into (37) and by combining (35), (36) and (46). As a result, the system we work with includes 19 equations: (25)-(34), (39)-(44), (58),

$$C_t + I_t + \beta E_t \frac{\lambda_{1t+1}}{\lambda_{1t}} B_{t+1} = Y_t + B_t \tag{59}$$

and

$$E_t \frac{\lambda_{1t+1}^*}{\lambda_{1t}^*} = E_t \frac{\lambda_{1t+1}}{\lambda_{1t}}\ e^{-\chi[B_{t+1}-\bar{b}]}. \tag{60}$$

The variables in the system are the state variables $[K_t,\ K_t^*,\ H_t,\ H_t^*,\ B_t]$, the co-state variables $[\lambda_{2t}, \lambda_{2t}^*, \lambda_{1t}, \lambda_{3t}, \lambda_{3t}^*,]$ and the control variables $[C_t, C_t^*, N_t, N_t^*, I_t, I_t^*, Y_t, Y_t^*, \lambda_{1t}^*]$

7.2 System of Equations—No-OC Model

$$\lambda_{1t} = [C_t - \psi N_t^{\nu}]^{-\sigma} \tag{61}$$

$$\lambda_{1t}^* = [C_t^* - \psi N_t^{*\nu}]^{-\sigma} \tag{62}$$

$$\psi \nu N_t^{\nu-1} [C_t - \psi N_t^{\nu}]^{-\sigma} = \alpha \lambda_{1t} \frac{Y_t}{N_t} \tag{63}$$

$$\psi \nu N_t^{*\nu-1} [C_t^* - \psi N_t^{*\nu}]^{-\sigma} = \alpha \lambda_{1t}^* \frac{Y_t^*}{N_t^*} \tag{64}$$

$$\lambda_{1t} = \lambda_{2t} \left[1 - \phi \left(\frac{I_t}{K_t} - \delta\right)\right] \tag{65}$$

$$\lambda_{1t}^* = \lambda_{2t}^* \left[1 - \phi \left(\frac{I_t^*}{K_t^*} - \delta\right)\right] \tag{66}$$

$$\lambda_{2t} = \beta E_t \left\{(1-\alpha)\lambda_{1t+1} \frac{Y_{t+1}}{K_{t+1}} + \lambda_{2t+1} \left[1 - \delta + \phi \left(\frac{I_{t+1}}{K_{t+1}} - \delta\right) \frac{I_{t+1}}{K_{t+1}} - \frac{\phi}{2} \left(\frac{I_{t+1}}{K_{t+1}} - \delta\right)^2\right]\right\} \tag{67}$$

$$\lambda_{2t}^* = \beta E_t \left\{(1-\alpha)\lambda_{1t+1}^* \frac{Y_{t+1}^*}{K_{t+1}^*} + \lambda_{2t+1}^* \left[1 - \delta + \phi \left(\frac{I_{t+1}^*}{K_{t+1}^*} - \delta\right) \frac{I_{t+1}^*}{K_{t+1}^*} - \frac{\phi}{2} \left(\frac{I_{t+1}^*}{K_{t+1}^*} - \delta\right)^2\right]\right\} \tag{68}$$

$$P_t \lambda_{1t} = \beta E_t \lambda_{1t+1} \tag{69}$$

$$P_t^* \lambda_{1t}^* = \beta E_t \lambda_{1t+1}^* \tag{70}$$

$$C_t + I_t + P_t B_{t+1} = Y_t + B_t \tag{71}$$

$$C_t^* + I_t^* + P_t^* B_{t+1}^* = Y_t^* + B_t^* \tag{72}$$

$$K_{t+1} = (1-\delta)K_t + I_t - \frac{\phi}{2}\left(\frac{I_t}{K_t} - \delta\right)^2 K_t \tag{73}$$

$$K_{t+1}^* = (1-\delta)K_t^* + I_t^* - \frac{\phi}{2}\left(\frac{I_t^*}{K_t^*} - \delta\right)^2 K_t^* \tag{74}$$

$$Y_t = A_t K_t^{1-\alpha} N_t^{\alpha} \tag{75}$$

$$Y_t^* = A_t^* K_t^{*1-\alpha} N_t^{*\alpha} \tag{76}$$

$$B_t + B_t^* = 0 \tag{77}$$

$$P_t^* = P_t \ e^{-\chi[B_{t+1}-\bar{b}]} \tag{78}$$

There are 18 endogenous variables: $C, N, Y, K, I, B, P, \lambda_1, \lambda_2$, for both countries. There are 18 equations: (61) to (78). We assume $\bar{b} = 0$ (no asset holding in steady state) and use the fact that capital adjustment costs are zero in steady state.

Recognizing that (linearized versions of) the two budget constraints (71) (72), the asset equilibrium condition (77) and the world resource constraint (58) are not independent, we follow what Baxter and Crucini (1995) did when solving the model by KPR. That is (1) we drop the foreign budget constraint from the system and include the resource constraint, (2) we make the Lagrange multiplier associated with the home budget constraint a co-state variable. In addition, we simplify the system by eliminating prices P and P^* by using (69) into (71) and by combining (69), (70) and (78). As a result, the system we work with includes 15 equations: (61)-(68), (73)-(76), (58),

$$C_t + I_t + \beta E_t \frac{\lambda_{1t+1}}{\lambda_{1t}} B_{t+1} = Y_t + B_t \tag{79}$$

and

$$E_t \frac{\lambda^*_{1t+1}}{\lambda^*_{1t}} = E_t \frac{\lambda_{1t+1}}{\lambda_{1t}} \ e^{-\chi[B_{t+1}-\bar{b}]} \tag{80}$$

The variables in the system are the state variables $[K_t,\ K_t^*,\ B_t]$, the co-state variables $[\lambda_{2t}, \lambda^*_{2t}, \lambda_{1t}]$ and the control variables $[C_t, C_t^*, N_t, N_t^*, I_t, I_t^*, Y_t, Y_t^*, \lambda^*_{1t}]$

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Table 1: Parameter Values

Preferences: $\beta = 0.993$, $\sigma = 2$, $\nu = 3$, $\psi = 6.174$.
Technology: $\alpha = 0.55$, $\varepsilon = 0.24$.
Capital accumulation: $\phi = 2.76$, $\delta = 0.02$, $\gamma = 0.95$.
Productivity shocks: $\rho = \rho^* = 0.945$, $\upsilon = \upsilon^* = 0$, $\sigma_\varepsilon^2 = 0.012^2$, $\tau = 0.323$.
Others: $\bar{b} = 0$, $\chi = 0.001$

Table 2 : Moments

Moment	**Data**	**OC**	**no-OC**
Standard Deviations (SD)			
$SD(Y)$	1.69–1.92	1.82	1.82
$SD(C)/SD(Y)$	0.75–0.83	0.54	0.48
$SD(N)/SD(Y)$	0.61–1	0.31	0.33
$SD(I)/SD(Y)^{\dagger}$	2.78–3.27	3	3
Cross-Country Correlations			
Y	0.29–0.66	0.31	0.29
C	0.12–0.51	0.43	0.27
N	0.33–0.43	0.32	0.29
I	0.25–0.53	0.15	-0.38
Others			
$autocorr(I)$	0.91–0.92	0.67	0.65
$corr(TB/Y, Y)$	-0.37– -0.31	-0.16	-0.46
$SD(TB/Y)$	0.39–0.62	0.15	0.87

Notes: † denotes a moment that is targeted in the calibration (see Section 3 of the paper). Numbers in the "Data" column are ranges constructed using the statistics reported by BKK (1995), Chari, Kehoe and McGrattan (2002), and Baxter and Farr (2005). Except for the trade balance, all data are in logs and have been detrended using the HP filter (BKK and CKM) or a band-pass filter (BF).

Table 3 : Sensitivity Analysis for Model with Organizational Capital.

	Table 2	Table 2	β	σ	(α, ε)	γ	$corr(\epsilon, \epsilon^*)$	ν
	no-OC	OC	0.984	3	$(0.55, 0.2)$	0.8	0.258	2
$corr(I, I^*)$	-0.38	0.15	0.17	0.16	0.06	-0.06	0.08	0.02

Figure 1a

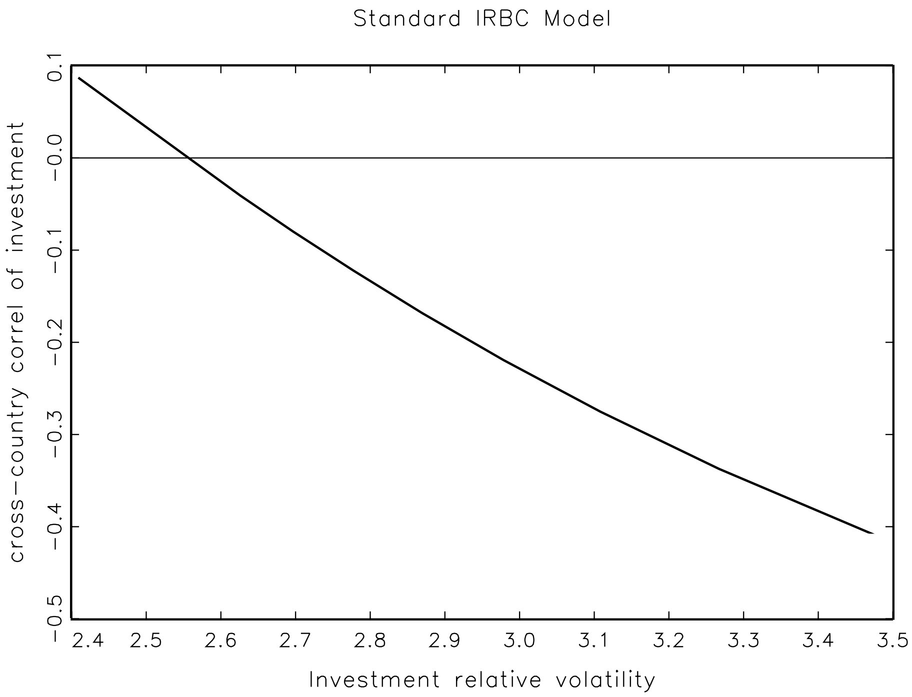


Figure 1b

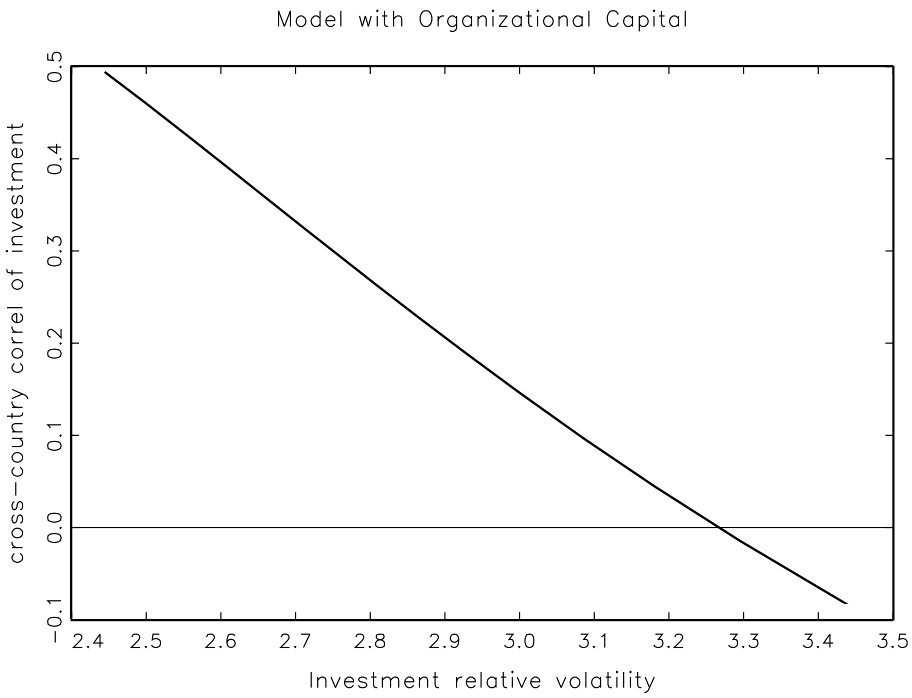


Figure 2

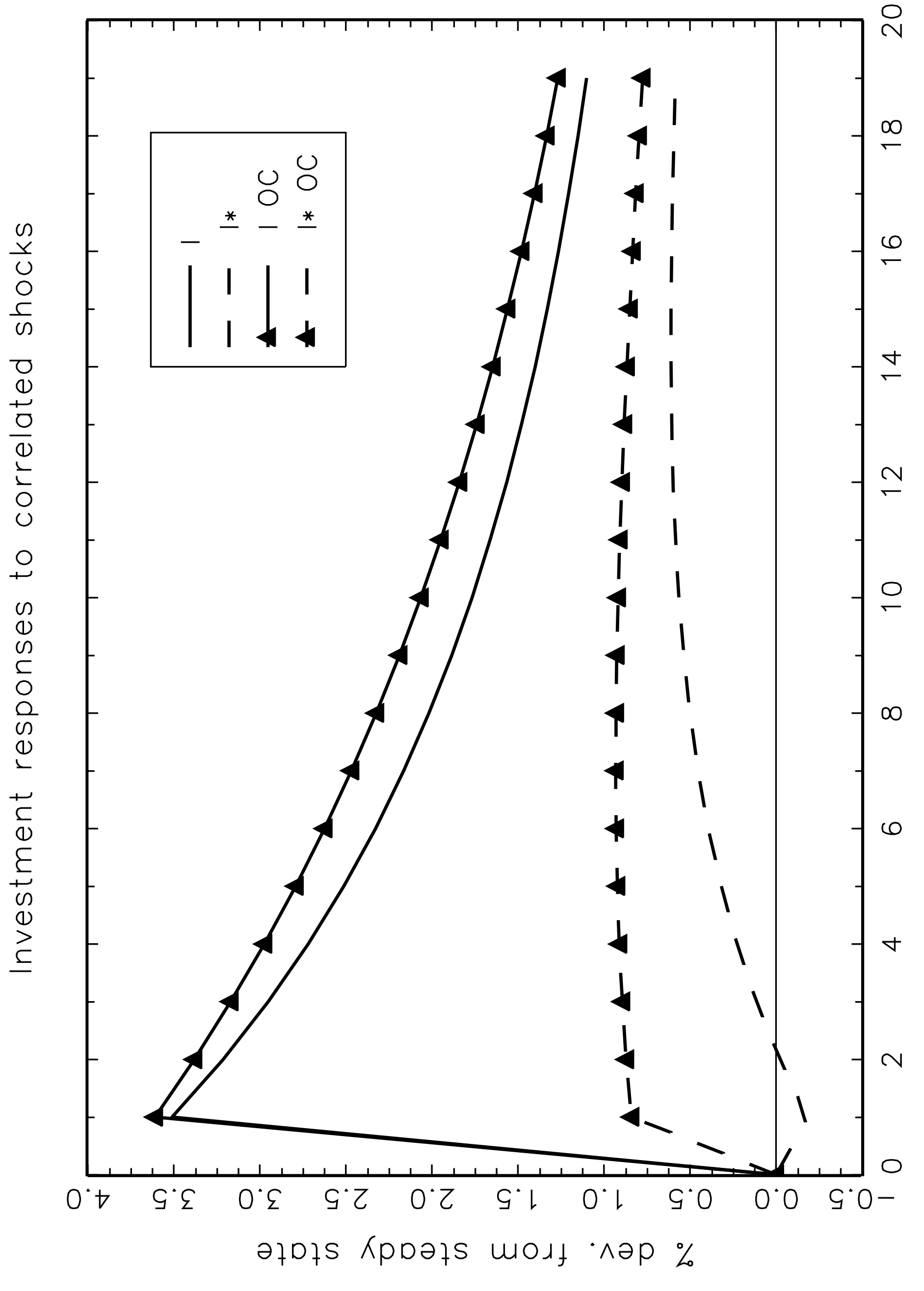

Investment responses to correlated shocks
I
I*
I OC
I* OC
Time
% dev. from steady state
0
2
4
6
8
10
12
14
16
18
20
−0.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0

Figure 3

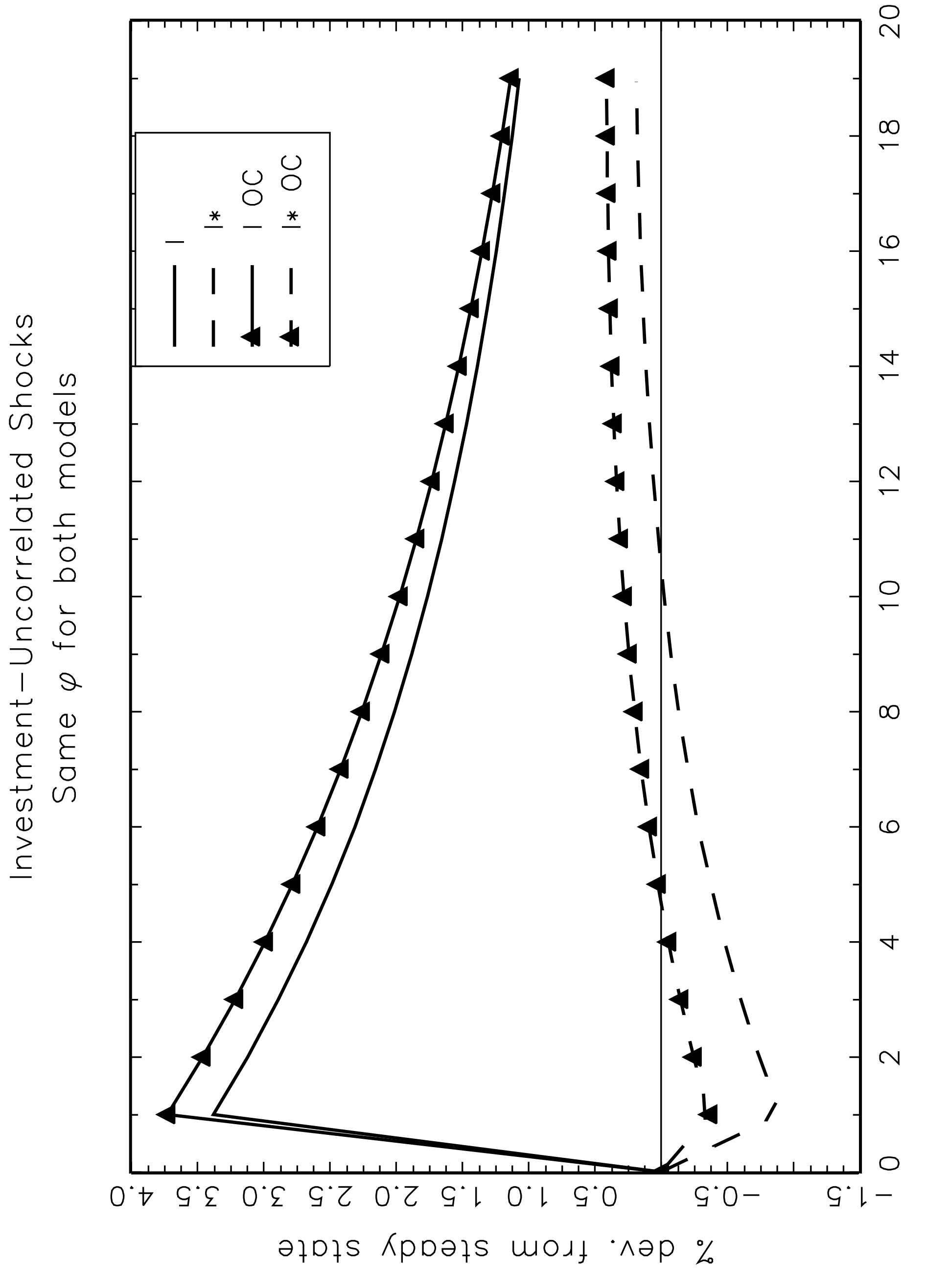
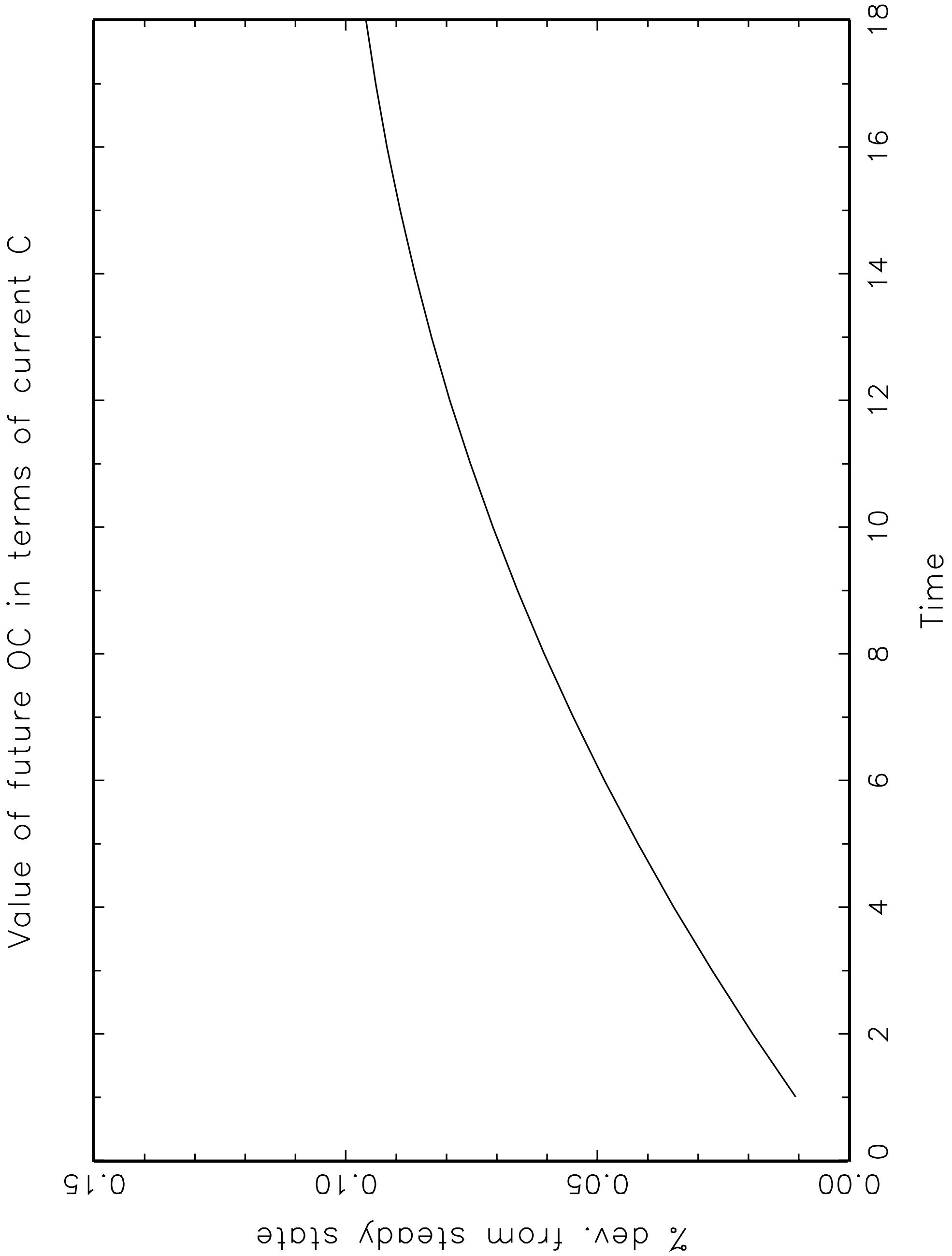

Investment−Uncorrelated Shocks
Same φ for both models
I
I*
I OC
I* OC
Time
% dev. from steady state

Figure 4



Value of future OC in terms of current C
% dev. from steady state
0.00
0.05
0.10
0.15
Time
0
2
4
6
8
10
12
14
16
18